

Three-body final state interactions in $D^+ \rightarrow K^- \pi^+ \pi^+$

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We stress the importance of three-body final state interactions in $D^+ \rightarrow K^- \pi^+ \pi^+$. The basic building block is the $K\pi$ amplitude with parameters determined by a fit to elastic LASS data. Based on a vector weak vertex, we can describe the $K\pi$ phase production experimental in the elastic region.

1 Introduction

Decays of D mesons became an important source of information about light scalars mesons, especially in the reactions $D^+ \rightarrow K^- \pi^+ \pi^+$ and $D^+ \rightarrow \pi^+ \pi^+ \pi^-$. We calculate three-body effects in the decay $D^+ \rightarrow K^- \pi^+ \pi^+$ and our main motivation is the discrepancy between the projection of $K^- \pi^+$ S-wave amplitudes from E791 [1] and FOCUS [2] experiments, and the scattering $K^- \pi^+$ S-wave from LASS [3]. To calculate the $D^+ \rightarrow K^- \pi^+ \pi^+$ decay, we need to deal with two independent families of processes: the weak vertex, usually treated by quark factorization techniques in the literature [4], and the strong final state interactions (FSIs), which do take place after the weak decay. We concentrate on the three-body structure of FSIs and aim at identifying leading effects. Technical details of our calculation can be found in [5]. Among the simplifications made, we mention the absence in the $K\pi$ amplitude of both isospin 3/2 and P waves, as well as couplings to vector mesons and to inelastic channels.

The $K\pi$ amplitude is an essential ingredient in the three-body FSIs. We employ an elastic amplitude inspired on chiral perturbation theory, eqs.(1, 2), supplemented by unitarization. The tuning to elastic LASS data [3] defines the three free parameters in (1, 2). This amplitude contains two poles, associated with the κ and the $K_0^*(1430)$.

$$(1) \quad \bar{T}_{1/2} = \frac{1}{F^2} [s + 3t/4 - (M_\pi^2 + M_K^2)] - \frac{\alpha(s)}{s - m_R^2},$$

$$(2) \quad \alpha = \frac{3}{2F^4} [c_d s - (c_d - c_m) (M_\pi^2 + M_K^2)]^2.$$

In our exploratory work, we assume three simple topologies for the weak amplitude, indicated schematically in fig. 1. The strengths of these vertices are respectively W_a , W_b and W_c , taken as constants, and their strong evolution is studied independently.

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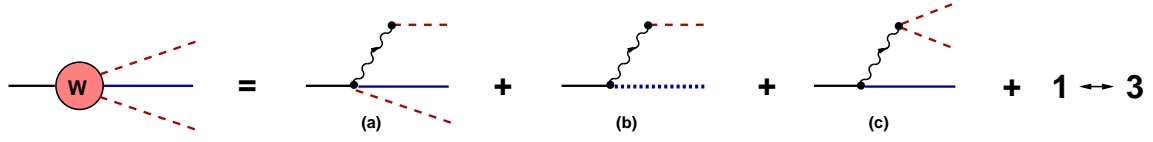


Figure 1: Topologies for the weak vertex: the dotted line is a scalar resonance and the wavy line is a W^+ , which is contractile to a point in the calculation; in diagram c, one of the pions is neutral.

2 Three-body FSIs

Our treatment of FSIs departs from a Faddeev-like integral equation, represented in fig.2 top, which is subsequently expanded perturbatively, fig.2 bottom. Terms in the FSI series

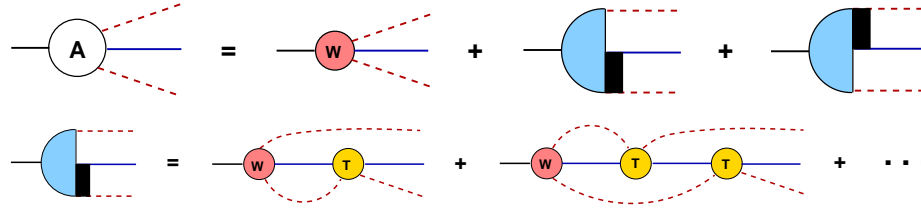


Figure 2: $D^+ \rightarrow K^- \pi^+ \pi^+$ decay: (top) partonic amplitude (red) and hadronic multiple scattering in the ladder approximation; (bottom) rescattering series implementing three-body unitary.

contain a recursive component, the $K\pi$ two-body amplitude. Each weak topology in fig.1 is coupled to this series, giving rise to the amplitudes A_a (fig. 3), A_b (fig. 4) and A_c (fig. 5). Processes arising from the weak vertex (a) in fig.1 involves a tree term, whereas the

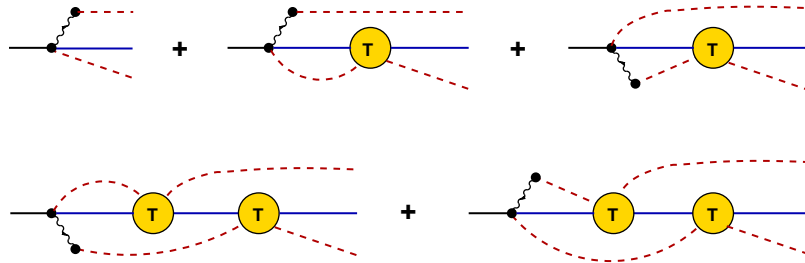


Figure 3: Diagrams involving the weak vertex W_a ; the wavy line is a W^+ , always plugged to a π^+ ; the π produced together with the \bar{K} on the opposite side can be either positive or neutral.

three-body rescattering series starting from the weak vertex b has to be treated properly in order to avoid double counting. The bottom line in fig. 4 represents the construction

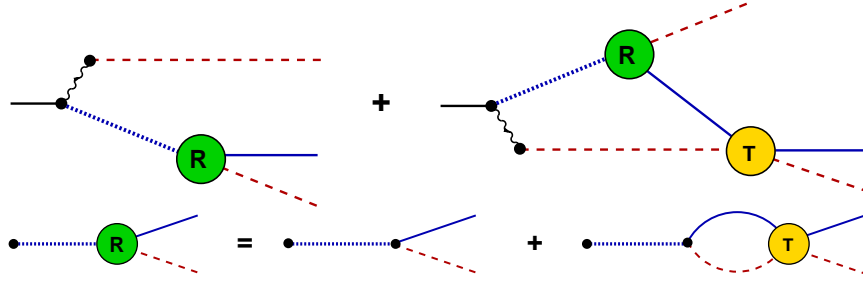


Figure 4: Diagrams involving the weak vertex W_b ; the wavy line is a W^+ , always plugged to a π^+ and the dotted line is a scalar resonance, which has a width given by the substructure R described at the bottom line.

of resonance width. In the case of process associated with the weak vertex c in fig.5, the series is simplified, since the π_0 produced directly from the W^+ decay is not present in the final state and the tree diagram does not play a role.

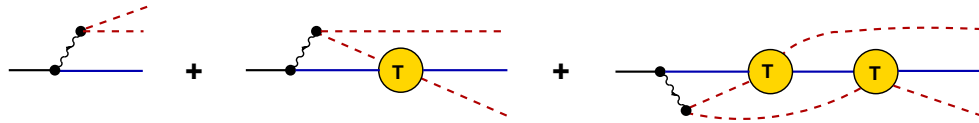


Figure 5: Diagrams involving W_c ; one of the pions in the weak vertex is neutral.

For simplicity, we show here contributions from FSI series up to a single rescattering. This is a good approximation, since higher order terms tend to decrease. In the case of A_a , the leading contributions are given in the first line in fig.3, which include both tree and one loop diagrams. In A_b , only the first diagram in the upper line of fig. 4 is kept and, in A_c , the leading term is just the one loop diagram in the middle of fig. 5. In graph 6, we show these individual contributions for the phase, compared with the experimental scattering (LASS) [3] and production (FOCUS) [2] data. As we can see, while contributions from A_a and A_b fall exactly over the elastic $K\pi$ phase, the amplitude A_c coincides with FOCUS data [2] up to the region of the peak, when shifted by -163° . The A_c topology is the only involving only a proper three-body interactions whereas A_a and A_b include tree contributions.

Thus, with a simple model of three-body final state interactions and a number of simplifying assumption we can reconcile experimental data between two-body interactions and weak decays, stressing the importance of proper three-body effects in the $D^+ \rightarrow K^- \pi^+ \pi^+$ decay amplitude. More calculation details can be found in reference [5].

Acknowledgements

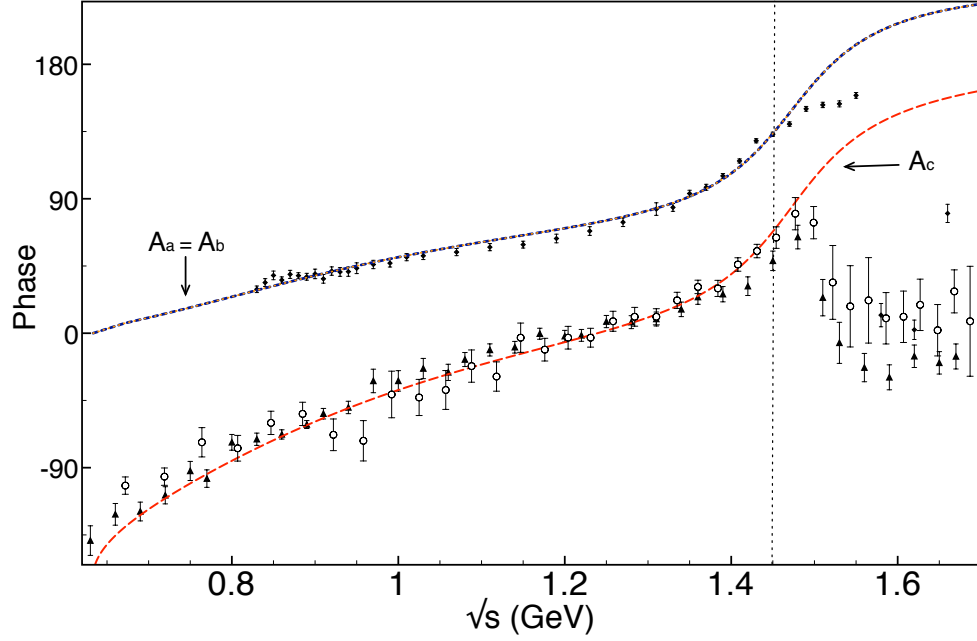


Figure 6: Leading contributions of the amplitudes A_a (blue dotted), A_b (orange dashed) and A_c shifted by -163° (red long dashed), compared with FOCUS [2](triangle), E791 [1](circle), and elastic $K\pi$ results from LASS [3](diamond).

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